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The Applicability of Adopting Lean Techniques in Construction Industry

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Abstract

The construction industry is one of the most significant industries in the Kingdom of Saudi Arabia, especially since the economic boom over the last decade that has resulted in large growth in the building of facilities and infrastructure around the kingdom. This study aims to assess the applicability of adopting Lean techniques in the local construction industry. Lean construction is a powerful concept that focuses on continuous improvement of the value stream by eliminating waste and increasing on the amount of value-added steps. The assessment relied on the three main points considered key factors in adopting Lean Construction: the awareness of staff about waste, the amount of waste generated and tools to eliminate it, and barriers to successful implementation of Lean Construction. A questionnaire was distributed to a sample of participants working in the industry to collect data about awareness. The average result reflects a moderate awareness of the staff. Also, a case study of the main processes of a large engineering construction and contracting company was conducted. The amount of waste generated was huge and Lean tools were suggested to allow for an efficient improvement on that processes. Finally, the expected barriers for implementation of Lean Construction were observed and sorted. In conclusion, the study found that Lean construction is applicable to be adopted in the local construction industry, but it needs direct support especially from top management.

Keywords: Lean; Construction Industry; Quality; assessment.

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1. Introduction

The construction industry is crucial for developing countries. It creates a path for the economy to grow. Consequently, many industries use infrastructure development to evaluate the future economic situation of that region. However, in any context, the construction industry faces challenges in meeting project requirements and constraints. These obstacles need a special developed treatment to come over them. To survive in a very competitive industry like construction, it is essential for companies to improve the quality of their outcomes, increase work efficiency, minimize waste and expenses, and maximize profits. This is required to compete within the current global situation and the economic recession. Because of that, new relationships must be developed between project speed, quality, and costs to gain a competitive advantage and survive the growth of the industry. Kingdom of Saudi Arabia is one country which has had enormous development in infrastructure and, consequently, the construction industry, since the last decade. This development has occurred during many economic stages over the past years, including a global economic recession and boom and then another recession and boom. During periods of economic boom, the number of infrastructure projects increase, in a race against time before the next recession to allow the country to develop as quickly as possible. Unfortunately, this desire for quick development had some negative impacts on the country. Abdulwahab AlQahtani states that the failure of many government projects in Saudi Arabia has been due to "awarding projects to non-qualified contractors and consultants without a fair bidding system, which has led to miscalculations in estimations, ultimately resulting in the failure of, or at least delays in completion of projects" [1]. AlQahtani remarked that "the more spending on projects, the higher the percentage of failures and delays"[1]. Mohammed Alashaikh, a State Minister in Saudi Arabia, said after announcing the budget of Saudi Arabia in 2016 that there are more than 7,000 projects that have experienced either delay or failure over the past 10 years, with a total loss reaching SR 1 trillion [2]. Until the Saudi Vision 2030 was announced late in 2015, there were no available governmental statistics from a respected authority such as the Ministry of Municipal and Rural Affairs showing the actual status of governmental projects and the numbers for generated waste. According to the report of the National Transformation Program 2020:

- The Ministry of Economy and Planning announced that the percentage of Stalled projects is 30% and the delayed projects 70%, which means that there was no project completed within the estimated time.
- The Ministry of Municipal and Rural Affairs in the same report showed that the projects, which ran beyond their budget by 6%, is 44%; moreover, 66% of the projects were delayed by more than 20% over the estimated time.
- The Ministry of Transportation also announced that the percentage of delayed projects for highways was 40%.

2. Objectives

This study examines Lean Construction applicability in the local market. It aims to:

- Assess and evaluate the awareness of waste, of the awareness of waste and the availability of any practices of avoiding it, if any, within the local construction industry.

- Study the areas (processes) in which Lean Construction might be best applied by conducting a case study of a large local construction company
- Study the barriers preventing or complicating the adoption of Lean Construction and recommend solutions.

3. Construction Waste

In a Swedish study of work value, Reference [3] studied construction workers' use of their work time. Their example is from a housing construction project and involved a trained observer following a group of construction workers for 22 days. The work time was divided into: 1) direct value-adding work, 2) preparations, and 3) pure waste. The conclusion of their study was that direct value-adding work constituted less than 17.5% of the work time, while preparations constituted 45.4%, and waste 33.4% [3].

Nabil Abbas completed a study on the construction waste in Saudi Arabia. His study focused on construction in Jeddah city due to the difficulty in getting information for the situation in the whole kingdom [4]. In his study, Abbas found that; "the approximate waste in the field of residential construction equals 1 billion Saudi Riyal without including the other governmental projects, and if we generalized this number to the cities with same level of development as Jeddah the result is more than 10 billion SR"[4]. Abbas characterized the phases which generated the waste as: **"**the design phase, which had the highest score of waste sourcing, Preliminary Study phase, Execution phase, Operation phase, and Maintenance phase. Abbas concluded his research with the main reasons for the waste: Manpower, Processes, Documentation, Equipment, Material, and Location [4].

4. Lean Concept

The Lean Enterprise Institute defines Lean thinking as "a systematic method for maximizing the customer value while minimizing waste. Simply, lean means creating more value for customers with fewer resources." Lean was developed starting from the Ford Production System (FPS) which was utilized to collect autos. FPS was the premise for the Toyota Production System. Then, Just-in-time production philosophies joined with the Toyota Production System (TPS), which evolved into Lean with smart automation and some other factors [5]. Since the 1950s, after WWII, Lean production or TPS has been developed and implemented successfully by the Toyota automotive company. There are seven categories of waste in the lean concept [6]. These types of waste have been described by Womack and his colleagues [7] as:

1. Transportation (Unnecessary movement of people, machines, goods or parts between processes).
2. Motion (Unnecessary movement of people, machines, goods or parts within a process).
3. Overproduction (producing or receiving more than required).
4. Waiting (waste generated by waiting for a process to complete or process to start or between process).
5. Inventory (either for raw material or final products which have storing expenses without any value adding to the costumers or consumers).
6. Over processing (processing more than required).
7. Rework (more defects result in extra time, costs and losses).

5. Lean in Construction

Ballard and Howell observe that Lean construction aims to increase value and minimize waste, which affects the time, cost and materials [8]. As Lean Construction Improvement (LCI) puts it, "Lean Construction (LC) is a project management philosophy based on a set of approaches developed in production management and adapted for the project management. LC targets the objectives of a Lean Production system, maximizing value and minimizing waste".

According to Salem and Zimmer lean construction is a continuous process to eliminate waste, matching customer requirements with a focus on the value stream map and pursuing perfection in the execution of construction projects [9]. The activities within the construction industry can be divided into two major activities: conversion activities, which create a tangible value-added change, and flow activities, which connect the conversion activities.

Although all the construction activities consume money and time, the lean philosophy insists that the conversion activities have a value-adding impact and so should be more efficient while the other non-value adding processes and activities should be removed or decreased [10]. Many studies of the sources of lean construction waste found that most of the waste is generated within the flow activities and by removing that waste the processes can be more Lean and produce more value from fewer resources [11].

Although the concept of Lean Construction is still new for many construction firms, many previous studies have shown that the cost reduction that results from using lean techniques is significant [10]. Ballard and Howell report that many countries such as the UK, USA, Australia, and Brazil have exploited the advantages that can be had from supporting the Lean construction techniques within their construction industry [8].

Lean concept might be difficult to apply in the whole construction industry. Thomasson asserts that this difficulty may not in fact be a physical one but a psychological one in the form of resistance to change [12]. Lewis claims that the adoption of Lean depends mainly on the culture of the organization, which he defines as the feelings, beliefs, values, and default assumptions for the staff of the organization [9]. For these reasons, cultural change might be considered a critical success factor for applying Lean Construction and reaping the rewards of its resulting advantages [13].

6. Findings and Discussions

6.1 Awareness of Waste of Organizations and Staff

A survey was conducted using questionnaires to assess the awareness of organizations and staff and evaluate the awareness of waste, consequences and the availability of any practices or techniques within the local market to deal with it. Participants were chosen based on their involvement in the local construction industry and based on their position, department, years of experience, qualifications, working hours and other aspects. The questionnaires consist of 8 closed-end questions/statements, as shown below in Table 1. The results for each statement are presented in Table 1 as well:

Table 1: The results for Y/N questions

#	Statement/Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	Have you experienced any waste management tools in your organization?	Yes	42.11%		No	57.89%
2	Have you heard about Lean concept?		10.53%			89.47%

These results show that not only is waste management underutilized, but also knowledge of the Lean concept is almost totally lacking

Table 2: The results for the awareness of waste in the industry

#	Statement/Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
3	Wastes are serious problem facing the local construction industry.	0.00%	0.00%	10.53%	68.42%	21.05%
4	Construction waste is greater than Manufacturing waste.	0.00%	5.26%	31.58%	47.37%	15.79%
5	Wastes have a direct effect on the company performance.	0.00%	5.26%	10.53%	47.37%	36.84%
6	Traditional project management procedures can't deal with wastes.	21.05%	52.63%	5.26%	10.53%	10.53%
7	Dealing with waste depends on management willingness and equally on staff and labor's awareness.	26.32%	21.05%	10.53%	21.05%	21.05%
8	Companies are considering and dealing with waste properly	5.26%	26.32%	15.79%	31.58%	21.05%

From the previous results for the questionnaires Table (2) the awareness level of construction waste and its impact is moderate. Generally, the awareness in the results was related mostly to one type of waste: waste of material. These numbers reveal that construction companies must have lean concept to reach a better level of awareness, which will lead to improvement in waste reduction in the overall industry.

Next, a list of Lean tools was distributed to the participants. It was shown that the participants were familiar with some of them, especially after each tool was defined for them. As shown in Figure (1), "Root Cause

Analysis" comes at the top with 19 points from the whole participants and KPIs is the next with 15 points and so on.

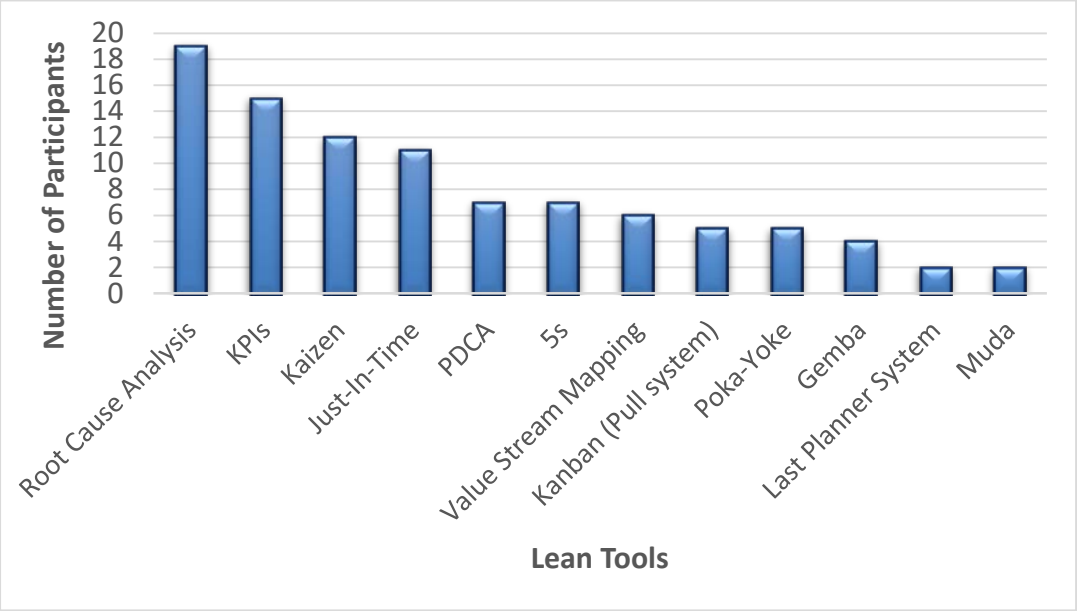

Figure 1: Pariticpants' awareness of Lean Tools

6.2 Evaluating Some of the Major Processes and Discovering the Waste

The local construction industry in Saudi Arabia has grown substantially, especially in the last decade, with a variety of large companies involved in projects. For this study, a common case study was choosing as the most effective tool for examining the construction market and evaluating the waste generated during a construction project. A large local construction company that is one of the leading companies in the industry in Jeddah was chosen as the case study. A brief study was conducted of three processes common in construction projects that are repeated on a daily basis request for inspection, request for material from warehouse, and requesting drawings for approval and waste outcomes were measured using VSM.

6.2.1 Process of Request for Inspection (RFI)

Quality of work in the construction industry is a crucial element to success. Thus, there are a lot of systems and policies to assure and control the quality for each step and activity, both in the design stage and execution stage. One of the most important procedures is Presenting the work done by the contractor to the consultant/client to get approval. This process is done through a form called "Request for Inspection." Once the request is sent from the construction department to QA/QC department, the assigned QA/QC engineer starts an internal inspection and makes sure that the work is done as per specifications and drawings. Then the request is sent out to the consultant/client for the final inspection and approval. For the chosen company, the submission of RFIs is done 2 times per day, with each time consisting of an average of 60 RFIs for Civil, Structural, and architectural aspects. The sketch below (Figure 3) presents the full process as it is for now (current-state) using a Value stream mapping technique.

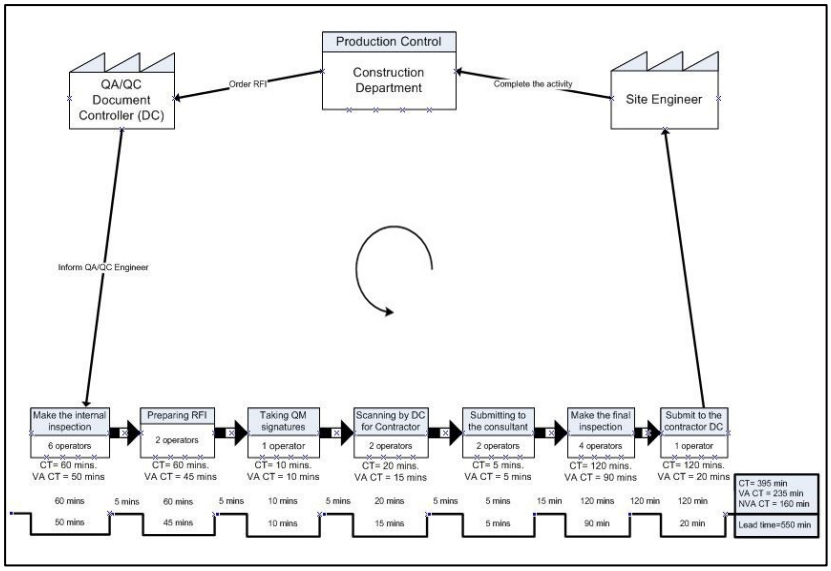

Figure 2: Current State for Request for Inspection using VSM

The process shown in Figure (2) is typical of each of the 60 RFI submissions (current-state) presented to the consultant. The total lead-time for closing this bunch of RFIs, from the creation of the requests until they are sent back, is 9.16 hours. From this 9.16 hours, the actual Cycle Time without considering waiting and traveling time is 6.66 hours, with Actual Value-Added time of 3.92 hours and Non-Value-Added time of 2.67 hours. Thus, to reduce the waste in this process, the system should be reengineered to eliminate the over-processing that is clearly present. In other words, some steps must be eliminated because they are not adding any value in the stream. From the result, It is recommended to adopt the use of an online system. The electronic flow can eliminate the waste generated from waiting, traveling from one department to another or to the consultant, and the necessity of scanning of the documents by the contractor or the consultant. The future-state after considering the suggested idea is shown in Figure (3).

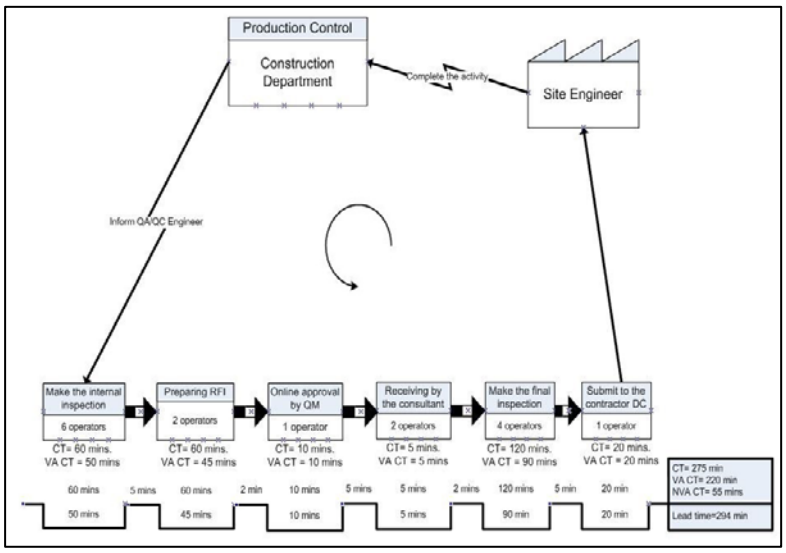

Figure 3: Future State for Request for Inspection by VSM.

As shown, the future-state will result in a valuable reduction in the overall time to complete the process. The lead time would be reduced from 9.16 hours to 5 hours. The cycle time would decrease from 6.6 hours to 4.6 hours. The actual Value-Added time would not change much (3.66 hours) but the non-Value-Added time would decrease to 0.92 hours from 2.67 hours. Instituting the suggested changes would not only eliminate waste in terms of time, but would also dramatically reduce the waste in terms of material (papers, ink), requiring no physical materials as compared to an average of 10 sheets of paper/RFI, an average of 600 papers for each submission.

6.2.2 Process of Requesting Material from Warehouse

The second repeated process, requesting material from a warehouse, typically involves a site engineer submitting a request to the procurement department for the requested material. The Procurement/Material department checks its inventory and then forwards the order to warehouse keeper. From there, the material is found, loaded for transport and then sent to the location Figure (4) presents a case for unusual materials which are not requested on a daily basis.

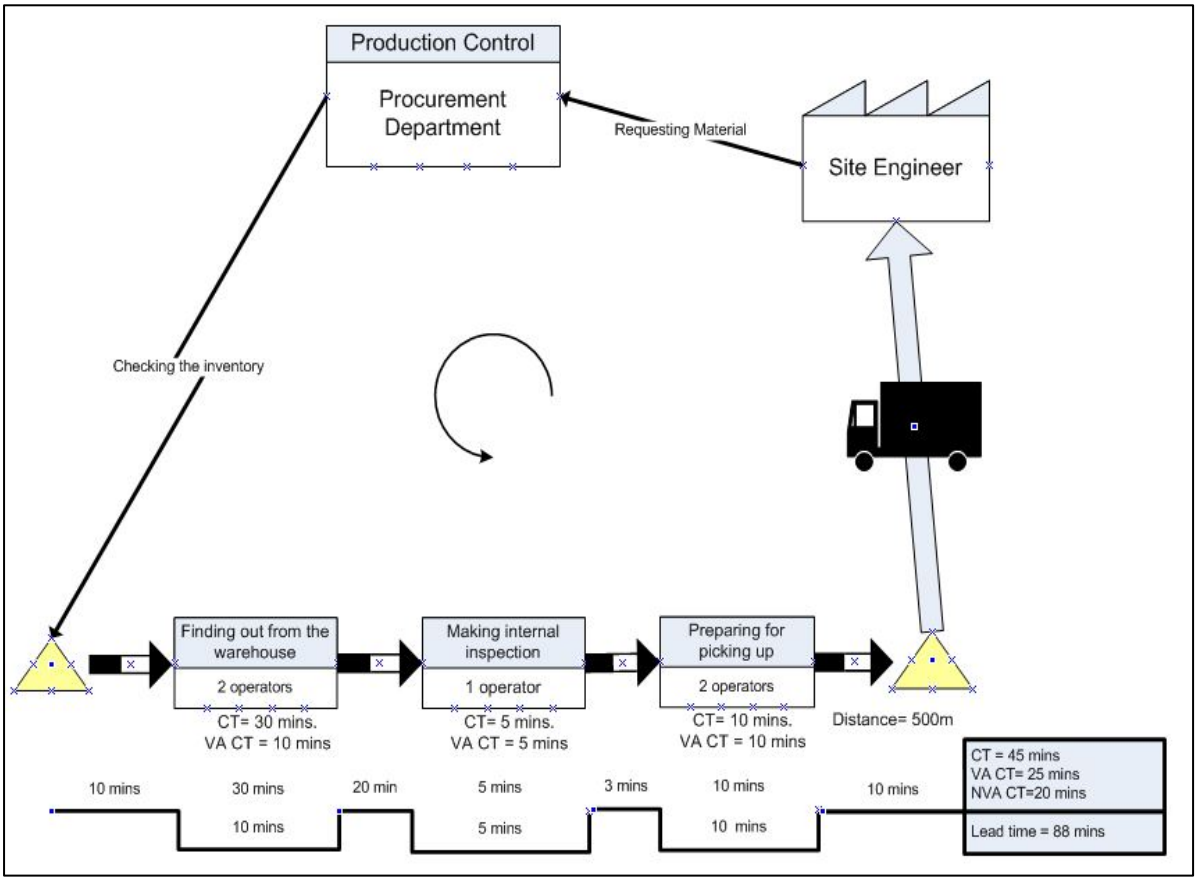

Figure 4: Current state for requesting material from a warehouse using VSM

For the entire process, from requesting the material and starting the process, the total lead time to receive the order at the location was 88 mins = 1.47 hour. The majority of this time was divided between finding the material in the store (30 mins) and waiting for the QA/QC Engineer to make an internal inspection (20 mins).

The total Cycle time was 0.75 hours with a value-added time of 0.42 hours and a 0.33 hour is Non-value added time. To minimize the waste, some tools must be adopted based on the root cause of the waste. On issue is the arrangement and sorting of these products in the project warehouse, which is huge. Currently it is divided into 4 areas based on the type of material. However,

this is not optimum. Also, the amount of materials purchased usually exceeds the amount required to complete the project which consider is a waste. Both of these issues cause operators to have some difficulty finding the material and preparing it for dispatch, especially for the material, which are purchased before its due date. The final source of waste is transportation; the distance between the warehouse and activity location in the site was almost 500 m and so it took about 10 mins to reach the exact location. To eliminate these waste generators, each waste source must be analyzed a solution determined. Firstly, some techniques like 5S must be adopted. 5S is a Toyota Production System tool which focuses on minimizing the waste and includes ways to minimize the amount of time consumed searching for materials and injuries resulting from a poorly –prepared, on-organized working place. Overall, it is a philosophy of taking care of the workplace that includes organizing and cleaning. It consists of five elements: Sorting: Sort out the necessary from unnecessary, and discard unnecessary. Simplifying: Create and identify a place for everything based on how often we use it. Sweeping Physical and Visual Control of work area. Standardizing: Create standard ways to keep the work areas organized, clean and orderly and document agreements made during the 5S's. Sustain: Put in place systems to assure the continuity of the processes. A perfect application of 5S will lead to a reduced time finding the material in the warehouse to a fixed time of 2 mins as opposed to the 30 mins in the current state. This short time finding the material will result in calling the QA/QC engineer for internal inspection even before the material is found because there is no issue locating it; this also will reduce the required number of operators to only one. As a result, we can use this operator to help in preparing for dispatch and reduce the time to be 5 min instead of 10 mins. Also, relocating the warehouse closer to the site -within 100 m- could reduce the transport time from 10 min to 5 mins.

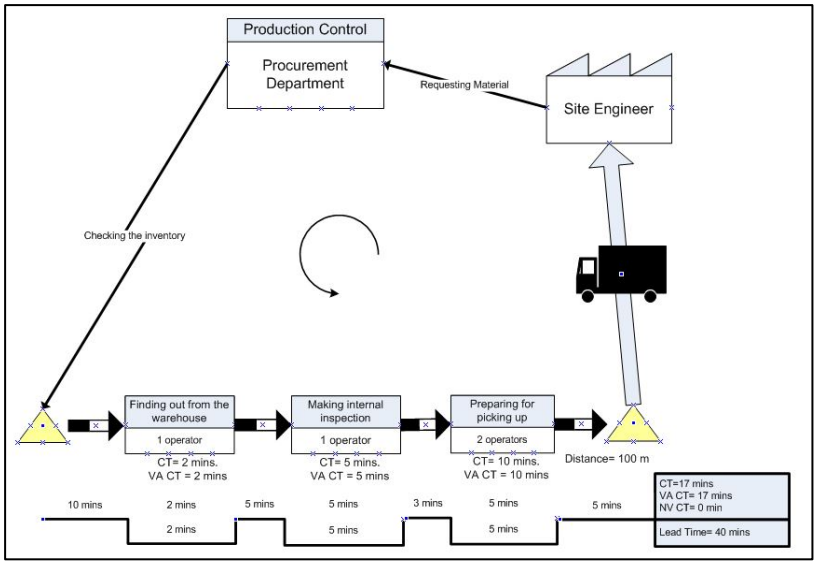

Figure 5: Future State for Requesting Material from the Warehouse using VSM

Overall improvement in Future-state (Figure 5) is as follows:

- Lead time = 0.66 hours from 1.47 hours.
- Cycle time = 0.29 hours from 0.75 hours.
- VA Cycle time = 0.29 hours from 0.42 hours
- NVA Cycle time = 0 hours from 0.33 hours.

6.2.3 Process of Requesting Drawings for Approval

Issuing drawings for approval is an essential activity within construction industry. A design is submitted as a shop drawing for approval until it receives the final approval. This process usually happens smoothly and follows a process routine to not just a particular company, but for all companies within the industry. Thus, this part of the study isn't focusing on the process of issuing drawings for approval largest sources of waste in terms of time is late discovery of missing drawings or finding that the drawing doesn't meet the situation in the site because of some revisions. This situation happens at least once per month. For example, sometimes they don't note that there are missing drawings for a slab until they reach it. This scenario used to stop the work until the drawing issue was resolved by designing new drawings. The procedure for designing, revising, submitting, approving and waiting to receive the drawing back takes at least 7 days. From the previous description, the root causes for this mistake are:

- Lack of coordination and planning between the engineering team and construction team
- Lack of presence of a design engineer to follow the actual progress and situation in the site.

Lean construction has some very powerful tools to deal with this situation. These tools are:

a. Last Planner System (LPS): This is a collaborative process which insists on a pull system for information, ideas and documents. It works backwards from a target by considering the steps in reverse to remove any expected and non-expected constraints. It promises reliable targets that can be achieved efficiently. LPS contributes four elements:

1. Master Scheduling: This is something common for any company; whether applying lean or not, they must have a master schedule from the beginning of the project to determine the milestones and work strategy.
2. Phase "Pull" planning: This part is helpful to smoothen the work flow. It is carried out by different parties, starting from managers and including the staff and foreman down to subcontractors. This planning ensures sorting of activities and resolves conflicts before they start. Typically, all the parties involved in the project are brought together and pull the schedule backwards from the target to identify any constraints.
3. Make Work Ready Planning (Look ahead Planning): This element is to make sure that major activities can begin. It is suggested to look not less than six weeks look ahead.
4. Weekly Work Planning: This also is one of the feature common to all construction companies. But

here, it's done to create a performance commitment by the responsible person to meet the time and the schedule. In this phase, the involved parties are accountable because of their participation in the overall schedule.

b. Gemba (The Real Place): This is a Japanese concept of continuous improvement which is designed to enhance processes and reducing waste. This tool insists on the appearance for the responsible person at the site instead of in an office, and in front offices instead of back offices; this leads to problems being visible and continuous improvement will be based on direct information without any distortion. Adoption of this tool by the Engineering Department will allow it to see the actual situation and make any changes in early stages instead of waiting for feedback from site engineers.

Adopting these lean tools, LPS and Gemba, leads to creation of a productive environment with a minimum number of constraints and mistakes. In this way, the company can avoid mistakes or some missing approved drawings and eliminate the resulting waste.

6.2.4 Barriers to the Successful Implementing Lean Construction

The construction industry is a solid industry from the perspective of systems, processes and procedures. Systems among companies are generally the same globally. Many trials have been done to adopt several techniques from manufacturing to use in construction but the results have often been rejected based on the difference between these two industries; the construction industry claims that manufacturing has a continuous repeated process with a typical product while construction has a different unique product each time. This part of the study sheds light on the main barriers which prevent or complicate the successful adoption of Lean Construction based on observations within the whole industry. These barriers are:

- Lack of Management Support and Commitment: The successful adoption of any new strategy or innovative idea must be supported by the higher management. Usually, the top management level in the construction industry avoids making any strategic change to the systems.
- Lack of Adequate Awareness of the System: Lean principles are widely known in the manufacturing, but in construction it is still a bit of a mystery. Generally, the awareness of waste and its impact need to be improved, and after that Lean Construction might be introduced.
- Human Nature and Attitude: One of the most common human behavioral issues is resistance to change Changing human traditions of work is essential and considered as a prerequisite for implementing Lean Construction.
- The Number of Involved Parties (Fragmentation): Due to the large number of participants in construction projects, it is difficult to have a sustainable implementation of Lean Construction. Each subcontractor (party) has his own priority, which might not agree with those of the main contractor. Strong communication is needed to remove this difficulty.
- Educational Issues: Lack of technical skills, inadequate training and poor understanding of the workflow can destroy the startup of implementation of Lean Construction. This issue can create a serious threat to the overall organizational system.

- Financial Issues: Although Lean Construction implementation will result in an increase in profits by removing the waste and increasing value, it requires additions to the budget at the beginning of implementation for training and hiring of experts. This will lead may cause managers to discard the Lean Construction as an option and follow the traditional system.

7. Conclusion

Lean Construction is a concept which is derived from Lean principles for manufacturing. It focuses on continuous improvement of work flow, increasing the value throughout the system and eliminating waste. Although the waste generated from construction is often enormous, whether in terms of material or time, and this concept can help companies reduce waste, Lean Construction is not exploited efficiently in the construction industry. This study focused on assessing the applicability of adopting Lean Construction in the local construction industry. This study consists of three parts in its effort to determine the barriers to the adoption of Lean Construction:

1- Assessing the awareness of people/ staff working in the industry about waste and solutions; this gave us an idea about the perspectives of people in the industry. This assessment concluded with an overall result showing moderate awareness among professionals of Lean Construction.
2- Evaluating some of the common processes in construction using a case study of one of the large construction companies in Saudi Arabia; this was to prove the need for a waste management concept. The studied processes were:

- Request for inspection process
- Material requesting processes
- Requesting approval of drawings

The waste generated throughout the process was very high and application of Lean concept and tools reduced the total lead time by an average of 40%.

3-Identifying barriers to the successful implementation of Lean Construction; to adopt new systems or ideas, the barriers must be studied to assure successful and effective implementation. The study identified 6 main barriers as follow:

- Lack of Management Support and Commitment
- Lack of Adequate Awareness Throughout the System
- Human Nature and Attitude
- The Number of Involved Parties (Fragmentation)
- Educational Issues
- Financial Issues

In sum, the current situation of the market can be improved by lean construction, the average awareness of

waste and Lean Construction is moderate, the activities and generated waste do fall under the Lean concept, and current barriers to the adoption of Lean Construction are not difficult to resolve. It seems some effort and willingness can result in a huge improvement.

8. Recommendations

Based on the data collected, analysis and results, here are recommendations and suggestions for adopting Lean in the construction industry:

- Increase the awareness of waste of all types and obtain commitment and support by top management. This will lead to the resolution of all the other barriers and ease the application of Lean Construction.
- Lean Construction has a lot of powerful tools that can help organization to reduce waste.
- Adopting Lean Construction might cause financial issues for the companies at the beginning, but once the adoption is completed, the results can be surprising with a great development in profits and quality.
- Currently, the local construction industry is suffering with a lack in number of projects and the resulting high market competition; therefore, construction companies must start new ways of work by eliminating the huge percentage of waste in order to survive.
- Manual flow of information must be changed to be electronic. This will allow for development as in the first process (RFI).
- Adoption of a Last planner system can eliminate all the obstacles resulted from discoordination and unexpected difficulties.
- The 5S tool should be strongly considered as it is very effective for arranging and organizing the warehouse to eliminate the wastes generated into the store.

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